
8.0 Shift Management: The Role of Fatigue in Human Error

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EXECUTIVE SUMMARY

This report has been prepared by the Centre for Sleep Research based at the University of S.A. The Centre is a member of the Australian Research Council Key Centre for Human Factors and Applied Cognitive Psychology. The Centre for Sleep Research is acknowledged as an international centre of excellence for fatigue research and policy development. The Centre has an international reputation for high quality basic applied and evaluative research in the areas of sleep, shiftwork and fatigue management. In particular, the Centre has worked extensively with the Australian transport industry in the design and evaluation of fatigue management programs.

It is our opinion that the major causes of fatigue are loss of sleep due to changing economic and social patterns over the last few decades. In general, many workers in the transport sector are now required to work longer, more flexible hours at reduced staffing levels. This, in conjunction with increasing task demands and social pressures have resulted in significant reductions in the quality and duration of sleep.

The effects of increased levels of fatigue on human performance and the community are profound. Research by our group and others has demonstrated that fatigue-related impairment is not dissimilar to the effects of moderate alcohol intoxication. In humans, fatigue delays response and reaction times, negatively impacts on logical reasoning and decision making and impairs hand-eye co-ordination – all critical safety issues in the transport industry. A significant body of research has concluded that fatigue is rapidly emerging as one of the greatest single safety issue now facing the transport sector.

Like alcohol intoxication, fatigue-related impairment is a major source of accidents and injuries and represents a significant social cost to the community. Recent estimates suggest that fatigue-related accidents and injuries, lost production and indirect subsidies cost the Australian community over 1 billion dollars annually. Indeed it can be argued that inter modal differences in prescriptive hours legislation are anti-competitive under the Hilmer legislation.

In an attempt to address the hidden economic and social costs associated with fatigue, the Centre for Sleep Research has been instrumental in the development, implementation and evaluation of an innovative and comprehensive fatigue management program for the Australian Rail Industry. This project has already produced:

- !Comprehensive, organisation wide training and education materials,
- !Workplace-based fitness-for-work testing sensitive to fatigue, drug and alcohol related impairment.
- !Software based fatigue modelling and management systems
- !Risk management systems for controlling fatigue as an 'identifiable work place hazard' under Occupational Health and Safety legislation.

This program and resources are now being developed for other industries including aviation, marine, mining and road transport employers.

The lessons learned from our industry-based collaborations suggest that responsible fatigue management requires fatigue to be managed as an Occupational Health and Safety issue rather than as an industrial issue. Moreover, fatigue management should be viewed as a shared responsibility. Employers have a 'duty-of-care' to provide safe work schedules that permit an adequate amount of time for an employee to sleep, rest and recover as well as fulfil their social and domestic responsibilities. Conversely, employees have a 'duty-of-care' to use their time away from work in a safe and responsible manner. That is, to ensure that they obtain sufficient sleep and recovery in order to complete their work duties in a safe and responsible manner.

1. CAUSES OF, AND CONTRIBUTING FACTORS TO, FATIGUE

Significant industrial and cultural changes have occurred within the transport industry in recent years. These changes include, but are not limited to:

- Pressure to enhance capital utilisation
- Heightened competition within and between transport modalities
- Increasing financial expectations of employees
- Management pressure to decrease employee numbers
- Increasing perceived value of high hours of work and flexibility from employees

One of the main outcomes of these changes is that the transport industry workforce now work longer, more flexible hours, which often includes more shiftwork. There is little doubt that the productivity benefits that can flow from flexible rosters systems are desirable. Nevertheless, it is likely that employers and employees with little knowledge of the financial, biological and psycho-social impacts of shiftwork and fatigue could negotiate work systems that significantly compromise potential benefits.

Determining all of the factors that cause, and contribute to, fatigue has proved difficult. Furthermore, determining the relative importance of these factors under different conditions has been problematic. In part, this is because few shift systems have been exhaustively examined in the laboratory. Furthermore, the results from one roster assessment cannot necessarily be generalised to other rosters.

At the most basic level, fatigue can be viewed as the consequence of inadequate restorative sleep. There are many factors that reduce sleep opportunity including:

- Longer hours: not surprisingly, when people work for more than 50 hours per week there is increasing competition between sleep and other activities of daily living.
- Night work: as the amount of night work increases, so does the amount of sleep that must be attempted at biologically inappropriate times. Sleeping 'out of synch' with the body's biological clock results in reduced duration and quality of sleep. This in turn reduces the restorative value of sleep obtained.

- Changing psycho-social expectations: For example, the increasing number of two income families means that both partners have less time available for family and social commitments. This can lead to a ‘social debt’ that can compete with the need for sleep.

Thus, the sleep deprivation and fatigue experienced by an individual may be largely dependent on the interaction between the roster and the individual worker’s social and domestic circumstances. Many ‘deregulated’ work schedules, particularly those that incorporate long blocks of night work, significantly reduce the opportunity for sleep and recovery between shifts. The research data indicates that shiftworkers obtain significantly less sleep than non-shiftworkers and the quality of that sleep is also significantly reduced. Sleep loss during night work is typically 1-3 hours per day. In the transport sector, these losses are at least as great and in road transport can often be significantly greater. Therefore, sleep deprivation can accumulate across a block of shifts, which leads to higher fatigue.

In addition to work-related causes of fatigue, non-work-related factors can also contribute to fatigue. Non-work factors such as sleep disorders, individual differences in coping strategies and psycho-social needs such as domestic duties can cause additional fatigue. As with work-related fatigue, non work-related causes of fatigue contribute to overall fatigue by a reduction in the opportunity for sleep and recovery. For example, the same roster could have quite different effects according to social circumstance. For example, a 12 hour night shift might have very different consequences for an 18 year-old single male living on his own compared to a 35 year old single mother of two toddlers without access to 24h child care facilities.

Taken together, both employers and employees have clear responsibilities with respect to managing fatigue. The basic responsibilities of both parties relate to ensuring that adequate sleep can be obtained between shifts so that fatigue does not reach dangerous levels during shifts. Thus, lack of sleep causes fatigue and sleep allows recovery from fatigue.

The most critical acknowledgement to make with respect to sleep and recovery is time of day. The quantity and quality of sleep that can be obtained in a break period of particular duration is significantly dependent on the time of day it occurs. For example, a 12-hour break from 0000h to 1200h may allow for a sleep of 7-8h duration, however, a break from 1200h to 0000h may only allow for 5-6h. To a large degree, this occurs because humans are programmed to sleep at night but is exacerbated by the fact that there are more needs competing with sleep during the day. Furthermore, a shift during the nighttime hours is more fatiguing than a shift performed during the day.

2. CONSEQUENCES OF FATIGUE IN AIR, SEA, ROAD AND RAIL TRANSPORT

TRADITIONAL CONSEQUENCES

As discussed above, fatigue results from not obtaining adequate quality and quantity of sleep, which can be contributed to by work and non-work factors. With respect to work-related factors, the most significant contributor is an increase in the number of hours that employees work and in particular the number of nighttime hours that employees work. In general, consequences of fatigue can affect:

- Individuals
- Organisations
- Communities.

Specific consequences can be categorised as being either:

- Biological
- Psychological
- Social.

INDIVIDUAL

The effects of acute sleep loss on individual performance are profound and affect a variety of areas including:

- **Biological:** Cognitive performance impairment leading to decreased ability to process information and make timely, appropriate decisions and actions.
- **Psychological:** Alertness impairment leading to decreased ability to remain awake. Clearly, such impairment can lead to increased likelihood of accidents and injuries.
- **Social:** Mood changes such as increased irritability, decreased motivation and morale.

Research by the Centre for Sleep Research at the University of S.A. has clearly demonstrated that fatigue-related impairment is not dissimilar to the effects of moderate alcohol intoxication. That is, significantly delayed response and reaction times, impaired reasoning, reduced vigilance impaired hand-eye co-ordination. [The international peer-reviewed research papers supporting this finding can be found in Appendix 4 and 5].

This research indicated that after 17 hours of wakefulness fatigue-related impairment on a hand-eye co-ordination task are equivalent to a blood alcohol concentration equivalent (BAC) of 0.05%. Furthermore, after 24 hours of wakefulness, impairment was equivalent to a BAC impairment of 0.10% - twice the legally prescribed limit. This level of fatigue is experienced regularly by many workers in the transport sector. This is particularly so in long distance road transport.

ORGANISATIONAL

These consequences clearly impact on many factors related to an individual's effectiveness within the workplace. For example, there is no doubt that increases in fatigue lead to higher utilisation of sick leave. Furthermore, observed decreases in morale, concentration and communication often relate to decreased productivity and increased accident rates. Consequences such as increased accident rates clearly have community repercussions.

COMMUNITY

Consequences at a community level include an increase in the use of medical facilities, a decrease in general community participation as well as increases in counselling and childcare requirements.

Below is a table that illustrates these relationships and gives examples for each interaction.

NON-TRADITIONAL CONSEQUENCES: IMPLICATIONS FOR NATIONAL COMPETITION POLICY

The effects of fatigue can be categorised on several levels. The more traditional categorisation, that is individual, organisational and community effects are documented above. We also believe there are important non-traditional consequences that are worth noting. We believe that differences in prescriptive hours legislation between transport modalities leads to significant anti-competitive outcomes. This argument is based on the idea of indirect subsidy to certain transport modalities relative to others based on the hidden social costs attributable to fatigue.

Recent research in the USA, Europe and Australia suggests that somewhere between 20-30% of all heavy vehicle accidents can be directly or indirectly attributed to fatigue-related impairment of the driver. Based on proportional gross domestic product (GDP) estimates in the US, fatigue-related accidents in the road transport sector probably cost the Australian taxpayer several hundred million dollars annually. For the road transport sector, it could be argued that the incidence and costs directly attributable to fatigue-related accidents constitute an indirect subsidy to the industry as the costs are typically borne by the tax payer.

If we view the hours of work permitted in the road transport sector relative to those permitted in rail or aviation it is clear that drivers in road transport are able to work much longer hours than is possible in these modalities. As a consequence, it is likely that the incidence of fatigue-related accidents is higher for road compared to other modalities. If this is the case, it is also likely that the aggregate social costs attributable to fatigue are higher for road transport relative to other modalities. Where these costs are not borne by the road transport sector, they constitute an indirect subsidy to the sector and, strictly speaking, could be viewed as anti-competitive under Hilmer legislation.

3. INITIATIVES IN TRANSPORT ADDRESSING THE CAUSES AND EFFECTS OF FATIGUE

THE AUSTRALIAN RAIL INDUSTRY: A CASE STUDY IN CO-ORDINATED PROGRAM DEVELOPMENT

A clear scientific understanding of the causes and effects of fatigue in the workplace has been accumulated over the last few decades. This research has led the scientific community to a general acceptance of fatigue as a source of neurobehavioural impairment. The effects of fatigue on brain function are not dissimilar to the effects of moderate alcohol intoxication ie., delayed reaction times, impaired reasoning, reduced situational awareness. Not surprisingly, fatigue has been identified as a major cause of accidents and injuries in the transport sector.

Despite the general scientific consensus concerning fatigue-related impairment, workplace changes have not yet reflected the increasing level of our scientific knowledge. Historically, transport sector employers and employees (through their representative unions) conceptualised fatigue as a simple function of total ‘hours-of-work’ . That is, fatigue increases linearly as a function of shift duration and decreases linearly as a function of break duration. Despite the fact that research has shown this to be patently untrue, most regulators continue to approach fatigue management with simplistic prescriptive hours policy based on shift and break durations.

With industrial de-regulation and the development of enterprise bargaining there has been a move away from descriptive awards, which encompassed most of the hours of work “regulations” in Australia. This new industrial flexibility has carried clear economic benefits, but has also resulted in:

- decreased staffing levels and subsequent work intensification
- increases in working hours
- lengthening of shift times (e.g. 12 hour shifts), with employees trading these off against extended periods of “off duty” time at home.

While there have been undoubted economic benefits of deregulation, there have also been inadvertent consequences associated with deregulation. In particular, there have been significant increases in work-related fatigue levels. In many cases, the cost consequences of these fatigue increases have not been factored into the cost benefit analyses of the industrial changes. In recent years, several studies have indicated that the initial benefits of industrial de-regulation have been accompanied by an increase in long-term social costs associated with changes in hours of work.

Many organisations are beginning to recognize the hidden costs associated with changing hours of work. This has been particularly so in the Transport sector. Many have decided to look at a more comprehensive costing model for industrial change and to look at the potential impact of these changes on the 'bottom line'.

During the early 1990's the Centre for Sleep Research (CFSR) at the University of SA was approached by several organisations including the SA Ambulance service, petrol tanker drivers at Mobil Australia, the RAAF, several companies within the mining industry including BHP, CRA and Brambles Coal Services. In each case the initiative arose from industrial negotiations, and the growing awareness that simple de-regulatory approaches to hours-of-work had resulted in significant unanticipated costs, particularly due to the effects of fatigue on health and safety.

In 1995, the CFSR was contracted to develop 'best-practice' guidelines for shiftwork and fatigue management by the Federal Department of Industrial Relations. [a copy of the main resource kit has been included as Appendix 2]. In this project we developed a model of fatigue in which responsibility was conceptualised as a 'shared responsibility' between employer and employee.

From this perspective, the employer was responsible for ensuring appropriate management of work-related causes of fatigue and the employee was responsible for ensuring appropriate management of non work-related causes of fatigue. In practice the employer was responsible for ensuring that the shift system provided sufficient time for an individual to rest, recover and carry out their normal activities of daily living. The employee was responsible for utilising the allocated time in a responsible manner. This

‘shared responsibility’ model was particularly attractive to employers and employees as it viewed shiftwork and fatigue as a shared problem and a shared solution.

In 1995 the CFSR was invited to participate in a major industry-based initiative to improve fatigue management in the rail industry. To date, this project is the largest and most comprehensive fatigue management program undertaken anywhere in the world. The most important aspect of this study is the unique collaboration of regulators, employers, employees and unions. A second critical issue has been the shift in perspective from fatigue as an isolated individual employee issue to one that views fatigue management as an integrated systems-based issue with responsibilities at all levels of the industry.

A consortium of industry representatives (including the union), researchers and regulators (in this case WorkSafe, Australia) was formed in 1995 and the first National Shiftwork and Workload Study commenced. The goals of the study were to:

- develop a comprehensive, industry-based training and education program that addressed the causes of, and countermeasures to improve the management of, work-related fatigue,
- develop and evaluate a field-based methodology for measuring fatigue in the workplace and identifying the principal determinants.

This study involved 253 train drivers from 14 rail depots across Australia. Each driver was studied for 14 days. Participation involved:

! Completion of an omnibus survey of work practices and coping strategies used by drivers.

! Collection of two weeks of sleep wake data using sleep diaries and computerised wrist actigraphy.

! Collection of urinary melatonin data to determine the effects of shifts on the ‘biological clock’.

! Collection of fatigue measures at the start and end of each shift across the two weeks.

The key points to emerge from this study were:

IFatigue [as well as drug and alcohol] related impairment can be measured practically and reliably in the workplace using computer-based performance testing (The OSPAT system).

IShiftwork produced little or no shift in the 'biological clock' particularly for irregular shiftwork.

The major determinants of fatigue were:

ITime-of-day at which shifts and breaks occurred

IDuration of shifts and breaks

IWork history over prior seven days

IBiological limits to recovery.

The major determinants of fatigue were then developed into a fatigue modeling software package that enables rail organisations to quantify and manage fatigue. That software package has been made available as both a commercially available software management system and as a public domain version available globally on the internet. [It is also worth noting that an aviation version of this software which enables changes across time-zones to be incorporated into the model has recently been developed for the RAAF. See Appendix 9]

The second, three year phase of this study has recently commenced. The goals of this study are to

IEvaluate the relative effectiveness of different implementations of fatigue management training programs.

IEvaluate the effectiveness of the fatigue modeling software developed in Phase One of the study. Specifically, the project will develop national guidelines for the use of the software. In addition, the industry will make operational and accident and injury data available that can be used to determine the relationship between levels of fatigue and accident and injury data.

Develop quantitative models to determine some of the social and economic costs of fatigue to the rail industry.

We believe the study provides an important model for fatigue management in the entire transport sector. The rail study provided a number of “pointers” for future initiatives. Some of its advantages were:

- With the alliance approach, and having multiple industry partners, it was extremely cost effective. In Phase One, the annual cost per partner [\$A20,000] was half than the cost of a junior administrative officer.
- The industry as a whole moved forward in lock-step on this issue, so it was competition neutral.
- It was developed and targeted specifically to the rail industry. As a consequence, there was a high degree of ownership by the industry and a high degree of penetration into actual management process.
- Its outcomes were comprehensive – improved safety, cost savings, and improved industrial relations.

Despite its benefits, an industry based approach had some drawbacks. Its main disadvantage was the difficulties in coordinating all the participants for meetings and decisions. However, given the historical difficulties in co-ordinated actions by the industry it was generally viewed by the consortium as less problematic than in other areas [cf. Standard gauge discussions which took almost a century to resolve]

According to the industry participants, the two key outcomes of the rail study generally applicable to industry were:

- An algorithm was calculated to enable the “theoretical” fatigue engendered by the roster to be validated against results from the rail and other studies. By entering the start and finish times of shifts into a simple spreadsheet, shifts can be scored and a fatigue “value” or “index” attributed to them. Shifts with high fatigue scores or peaks can be examined from a risk perspective and adjustments made to the roster if a reduction is warranted.

- Now the industry had a full fatigue management program available – a training and education package to help deal with both work and non work-related fatigue factors (lifestyle, social and family issues), and a computer based analysis of fatigue engendered in the workplace. A guide to the development of a shiftwork policy was also produced.

With increasing community awareness of fatigue as a safety issue, the CFSR has developed a reputation as a resource centre for advice and materials for industries taking initiatives on shiftwork and fatigue. Clients include companies such as Kimberly Clark, Australian Defense Forces, Port Waratah Coal Services, BHP, Brambles – as well as a number of international clients such as the FAA, Federal Office of Motor Carrier (USA) and Burlington Northern Santa Fe railway in the USA.

More recently, as both workers and management grappled with this increasing awareness of fatigue in the workplace the question “how tired is too tired?” inevitably arose. With the OSPAT program now tested and proven in the field, the latest initiatives have involved impairment testing. This can encompass **all** forms and sources of impairment, replacing separate drug and alcohol testing, but is used in the same context – fitness for work.

The interesting thing to note is that on the basis of research to date fatigue is up to four times more likely as a cause of impairment than drug or alcohol. Furthermore, whilst there is a relationship between impairment and the effects of fatigue and alcohol (in fact a very similar one) this is not so clear for other drugs. In fact some drugs – caffeine and amphetamine for example – may actually improve performance in the short-term.

This large database of experience is matched with a range of services from policy advice, to “tools” for measurement, to implementation of full fatigue management programs and systems.

It is our opinion that effective fatigue management systems require the following elements:

- The objective measurement of the causes and effects of fatigue.
- Evidence based policy – OH&S based, rather than industrial “regulation”.
- Programs should be comprehensive, and comprise the following elements
 - Training and education for all stakeholders in the understanding of fatigue and shiftwork.
 - Planning tools such as fatigue modeling of rosters and work arrangements.
 - Impairment testing programs, auditing the results of the previous initiatives.

Perhaps the most important lesson to be drawn from the CFSR’s experience to date is the importance of developing strategic alliances - partnerships between industry, unions, government, and researchers – to move forward on further initiatives to address fatigue in the transport industry.

4A. STRATEGIES TO INCREASE REGULATORY RESPONSIBILITY

It is our view that the major problem facing regulators are:

- Prescriptive hours legislation is inadequate as a means of controlling fatigue. Regulations that only address the length of shifts and breaks and which do not take into account ‘time-of-day’ factors cannot provide an adequate framework for managing fatigue.
- Employers and employees are bound under OH&S legislation to provide a demonstrably ‘safe system of work’. However, it is currently possible to construct shift patterns that comply with prescriptive hours legislation but are clearly ‘unsafe’ with respect to ‘duty of care’ requirements under the act. Equally, it is possible to construct shifts that comply with OH&S requirements for a safe system of work but are precluded under prescriptive hours legislation.

The resulting conflict between prescriptive hours legislation and OH&S legislation is difficult to resolve. The current system is industrially inflexible and does not manage fatigue in a rational manner.

From a practical perspective, it is preferable that any legislative changes associated with fatigue management do not necessitate the creation of new legislation or bureaucratic structures. This could be unnecessarily complicated and expensive and divert resources away from the effective development of fatigue counter-measures that would reduce the unnecessary social costs associated with fatigue.

To increase industrial flexibility and increase employer and employee responsibility for fatigue management we would recommend that prescriptive hours legislation should be eliminated and fatigue should be specifically defined and managed as an ‘identifiable workplace hazard’ and controlled under existing state and federal OH&S legislation. This would eliminate the current reliance on ineffective legislation and overlapping regulatory and reporting mechanisms.

This strategy would provide the following benefits:

- There is a pre-existing regulatory infrastructure for the development and delivery of policy guidelines and standards for managing fatigue.
- The use of OH&S legislation would be administratively simple. Procedures and mechanisms for identifying, auditing, managing and minimising fatigue are already in place.
- Most organisations have a pre-existing OH&S framework that could easily embrace fatigue management as an additional 'identifiable work place hazard'.

In addition to defining fatigue as an OH&S issue it is critical that fatigue should be managed in the context of a generalised risk management model. Fatigue should not be viewed independent of the task or activity undertaken. In simple terms, the maximum acceptable level of fatigue should be linked to the inherent risk of the activity. For example, it is clearly reasonable to accept a higher level of fatigue for less risky activities and vice-versa. Good risk management practice would suggest that a lower maximum fatigue level would be desirable for landing a jumbo jet or piloting a large ship in a difficult navigational channel than for operating a photocopier.

From this perspective, OH&S regulators could draw up codes of practice in which the maximum acceptable fatigue level is linked to industry-based risk assessments.

4B. STRATEGIES TO INCREASE COMMUNITY RESPONSIBILITY

At present there is limited community awareness of the social costs associated with fatigue-related impairment. As such, fatigue-related social costs have accrued either directly or indirectly for many years. There are several reasons for this:

- The central role of industrial relations in the development of hours-of-work legislation.

- The lack of systematic methods for determining the incidence, severity and social cost of fatigue-related performance-impairment, accidents and injuries.
- Technological limitations in our ability to quantify and measure fatigue.
- The limited expenditure on fatigue-related research projects relative to current estimates of the social cost attributable to fatigue.

If fatigue is to be managed rationally it is critical that the community costs of fatigue-related problems are quantified and any expenditure viewed as an investment in the reduction of the social costs attributable to fatigue.

We believe fatigue should be managed in a similar manner to the way the government approached alcohol related accidents and injuries in the workplace in the 80's and 90's. That is, the community perception of fatigue-related impairment should be considered morally and legally unacceptable to have an impaired worker operating in the workplace. It should be irrelevant whether the impairment is due to drugs, alcohol or fatigue.

This change of perspective could be best achieved by a federally funded national program to address the issue of fatigue management across all transport modalities. This might be best achieved through a collaborative project involving the Department of Transport and WorkSafe Australia and an appropriately constituted scientific reference group.

The project should consist of:

- An initial study to determine the best way of monitoring the social costs associated with fatigue. This study should determine what information and reporting mechanisms currently exist and what mechanisms need to be implemented in order to determine the social costs associated with fatigue.
- A research project to estimate the current and future social costs associated with fatigue in the transport sector. This could be used to determine an appropriate longer term budget to reduce the unnecessary social costs attributable to fatigue.
- A policy development program. This program should also ensure that fatigue policy is not anti-competitive with respect to different transport modalities.

- A research program quantifying the empirical relationship between fatigue, performance impairment, risk and social cost.
- An educational program to increase community and organisational awareness of the problem and ways to reduce the social costs.
- A fatigue countermeasures program to encourage initiatives that have potential to reduce the social costs attributable to fatigue.